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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.	:	10/615,877	Confirmation No. : 8460
First Named Inventor	:	Andrew L. SAMWAYS	
Filed	:	July 10, 2003	
TC/A.U.	:	1723	
Examiner	:	Charles E. COOLEY	
Docket No.	:	037141.52565US	
Customer No.	:	23911	
Title	:	CENTRIFUGAL SEPARATOR, ROTOR FOR USE THEREIN AND METHOD OF SEPARATING CONTAMINANTS FROM LIQUIDS	

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

CLAIM FOR PRIORITY UNDER 35 U.S.C. §119

Sir:

The benefit of the filing date of prior foreign application Nos. 0100989.3 and 0100993.5, both filed in the United Kingdom on January 13, 2001, is hereby requested and the right of priority under 35 U.S.C. §119 is hereby claimed.

In support of this claim, filed herewith is a certified copy of the original foreign application.

Respectfully submitted,

November 1, 2004

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Signed Stephen Hordley.

Dated 5 August 2003

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The Patent Office

Cardiff Road, Newport
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1.	Your reference	P650351GB
2.	Patent app **0100993.5** *(The Patent Office ...)*	13 JAN 2001
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Filterwerk Mann + Hummel GmbH Hindenburgstrasse 45 D-71638 Ludwigsburg Germany
	Patents ADP number *(if you know it)*	448571006
	If the applicant is a corporate body, give the country/state of its incorporation	Germany
4.	Title of the invention	Centrifugal Separation Apparatus
5.	Name of your agent *(if you have one)*	URQUHART-DYKES & LORD
	"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	GREG'S BUILDINGS 1 BOOTH STREET MANCHESTER M2 4DU
	Patents ADP number *(if you know it)*	00001644014
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(If you know it)* / Date of filing *(day/month year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing *(day/month/year)*
8.	Is a statement of inventorship and or right to grant of a patent required in support of this request? *(Answer "Yes" if:)* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body; see note (d)*	YES

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Claim*(s)*	- 8
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10 If you are also filing any of the following items state how many against each item:

Priority documents	-
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Statement of inventorship and right to grant of a patent *(patents form 7/77)*	-
Request for preliminary examination and search *(patents form 9/77)*	-
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Any other documents *(please specify)*	-

11 I/We request the grant of a patent on the basis of this application.

Signature Date 12/01/01

Urquhart-Dykes & Lord

URQUHART-DYKES & LORD

12 Name and daytime telephone number of person to contact in the United Kingdom

J Hammersley
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Centrifugal Separation Apparatus

This invention relates to centrifugal separation apparatus for separating particulate contaminants from liquids, such as engine lubricants, passed therethrough to effect cleaning, and in particular relates to rotor means used within such apparatus to perform the actual separation and retention of such contaminants.

Centrifugal separation apparatus is well known for use within the lubrication systems of vehicle internal combustion engines as efficient means for removing very small particulate contaminants from the constantly recirculated liquid lubricant over a long period of operation, such particulate contaminants arising from abrasion of the metallic components of the engine, decomposition of the lubricant and products of combustion.

Insofar as such separators are responsible for cleaning a liquid which is in any event circulated at elevated pressure, the art has concentrated on employing such lubricant pressure to effect rotation of parts responsible for generating centrifugal forces, and as such it includes rotor means comprising an essentially closed vessel, or canister, being supported for rotation about a rotation axis within a housing, and supplied with the liquid lubricant at elevated pressure at the axis. The canister is filled with the liquid and assumes a significant internal pressure before liquid is forced from the base (or other peripheral wall) of the canister by way of tangentially directed jet reaction nozzles, the reaction to said ejection causing the rotor canister and liquid within it to spin at high speed about the axis and thereby force solid particles to migrate from the liquid passing through the canister and agglomerate into a cohesive mass on the peripheral walls spaced from the rotation axis. The reaction nozzles, being directed substantially tangentially with respect to the rotation axis, at least in a plane orthogonal to the axis, define a reaction turbine.

It will be appreciated that the efficiency of separation is inter alia dependant upon creating the conditions in which any liquid entrained particle can migrate radially to the nearest deposition surface and is a function of the force acting on such particle and the time for which it can act. The former is a function of rotation rate and distance from the rotation axis. The latter is a function of the time taken for the entraining liquid to pass through the rotor canister (also called the dwell time) and the proximity of the deposition surface, and may be considered in terms of an effective dwell time, that is, influencing the contribution of the actual dwell time by positioning the contaminated liquid relatively to an appropriate deposition surface. However

both the rotation speed of the rotor canister and contained liquid, and the rate at which liquid is passed through, and ejected therefrom, are dependant upon the pressure drop between the canister contents and housing and upon the dimensions of the nozzles, within the constraints of such nozzle dimensions providing sufficient torque from the turbine to overcome inertial and frictional resistance to commencement of, and continuation of, rotation.

Within an internal combustion engine where lubricant is circulated under an initial (pumped) pressure in a range of about 2 to 6 bars that varies with operating conditions, a canister of relatively modest diameter, say 10 to 15 cms, and reaction turbine nozzles may achieve a rotation speed in the range of 4000 to 9000 r.p.m. which is sufficient for removing the relatively dense, contaminants of lubricant residue and metallic particles traditionally considered to be of principal detriment to the engine.

Examples of such reaction turbine centrifugal separation are shown in GB 731312, GB 745377, GB 2328891, US 5575912 and US 5906733, and it can be seen that as developments have been made to increase efficiency of separation, and range of separability, the degree of structural complexity has also increased, not least in optimising effective dwell time and/or placing the liquid to maximise forces acting upon entrained contaminants for the limited rotation forces available.

This is particularly true in respect of the dual goals of deriving maximum rotation energy from the liquid passing through the rotor whilst providing therein conditions necessary and suited to centrifugal separation of low density contaminant particles such as soot. Such contaminants are now seen as an important cause of engine wear, particularly in compression ignition engines, and require the lubricant to be provided with greater effective dwell time and/or be subjected to greater centrifugal forces than hitherto, notwithstanding that providing such conditions in theses arrangements also tend to militate against efficient flow of liquid through the canister.

Obtaining greater rotation rate from such a reaction turbine means ejecting liquid at a greater rate, by increasing the pressure and/or by shortening the dwell time or by increasing the volume of liquid contained, whereas attempting to cause the contaminant entraining liquid to traverse the canister at a greater radial distance from the axis is made difficult by the fact that the rotating liquid content of the canister creates a radial pressure gradient that tends to keep newly entered liquid away from the radially outer region of maximum centrifugal force (unless

internal structures are provided that add to the complexity and/or consume energy from the rotation), such that optimising such rotor canister is therefore not a question of simply increasing the radial dimensions of the canister but a compromise that nevertheless includes containing therein at high pressure a relatively large volume of the liquid lubricant to enable it to have a significant effective dwell time whilst it follows a tortuous path that involves interchanging potential and kinetic energy until it is ejected with sufficient energy for rotation production.

US 6017300 in particular explains in some detail that for properly separating very lightweight soot particles that can contaminate the liquid lubricant as products of combustion, the particles have to be subjected to higher centrifugal forces than readily available from such traditional, reaction turbine drive centrifugal separation arrangements, along with a longer dwell time, and proposes to elaborate upon the complex cone stack arrangement of US 5575912 by an external impulse turbine, the latter providing for high rotation operation and, being separate from the liquid for cleaning in the container, permits the contaminated liquid to have a longer dwell time.

It is also known from GB 731312 to have rotor means comprising two canister vessels coupled for rotation together, and each fed with differently sourced liquids, namely a fuel and a lubricant to be isolated from each other, and with one vessel driving both in rotation by turbine reaction to the liquid passing through it. However, in respect of contaminant separation the vessels function independently of each other with their respective liquids.

Insofar as these modified designs still adopt the principle of defining a rotor vessel whose radial dimensions are optimised for centrifugal forces on liquid entrained particles and function by filling it with the contaminated liquid and then effecting rotation at appropriate speed, they still exhibit significant rotor vessel inertia and have to provide energy to overcome frictional and other losses, providing a slow response, particularly in start-stop situations and involve a constructional complexity that may be difficult to justify economically, for instance where such low density contaminants are present in smal amounts or the unit cost of such rotor means relative to that for removing most of the (denser) contaminants has to be maintained.

It is an object of the present invention to provide centrifugal separation apparatus suitable for separating low density particulate contaminants from circulated lubricant of an internal combustion engine which is of simple and low cost form.

According to the present invention centrifugal separation apparatus for separating solid contaminants from liquid passed therethrough, comprises (i) a housing into which extends housing inlet duct means for supplying contaminated liquid thereto at elevated pressure and outlet duct means for drainage of cleaned liquid therefrom, (ii) rotor means, mounted within the housing for rotation about a rotation axis extending through the housing, and (iii) drive means operable to spin the rotor means about the rotation axis, the rotor means comprising primary and a secondary walled separation and containment vessels, each vessel having an impervious radially outer side wall extending about and along the rotation axis forming radially inwardly from the side wall an annular contaminant separation and containment zone, outlet passage means leading externally of the vessel to within the housing, and inlet means operable to convey liquid to be cleaned from the housing inlet duct means to the contaminant separation and containment zone, said primary vessel being arranged in operation to be filled with the liquid conveyed thereto, and the apparatus being characterised by said secondary vessel being arranged in operation to be not filled with the liquid conveyed thereto, the inlet means thereof being arranged to convey liquid to the vessel at a lesser rate than is capable of draining therefrom by way of the outlet passage means and the outlet passage means defining the boundary of the annular contaminant separation and containment zone radially inwardly of the outer side wall such that the liquid and contaminants separated therefrom are confined in the vessel to the annular contaminant separation and containment zone.

At least part of the secondary vessel may be arranged to surround the primary vessel with said contaminant separation and containment zone spaced radially outwardly of the outer side wall of the primary vessel, in order to maximise the rotation radius in this zone whilst not unduly increasing the axial length of the apparatus nor the volume of liquid rotated.

The secondary vessel may be releasably attached to the exterior of the primary vessel for rotation therewith, being easily removed for separate replacement and possibly retro-fitted to such existing primary vessel.

The secondary vessel is preferably formed of a low density material to minimise the effect of such secondary vessel on the inertia of the apparatus, and advantageously may be moulded from plastics material.

Notwithstanding the nature of the attachment of the secondary vessel to the primary vessel, the drive means for the apparatus as a whole may comprise the primary vessel, conveniently

employing the outlet passage means thereof as a reaction turbine.

The liquid conveyed to each of the first and second vessels may be liquid from the same source, or may be liquids, possibly different liquids, from different sources.

The inlet means for the secondary vessel may be at least in part the primary vessel, and possibly the outlet passage means of the primary vessel.

The secondary vessel may be mounted with respect to the housing for rotation about the axis by way of interfacing bush and spindle means lubricated at the interface with liquid from the housing inlet duct means and arranged to provide inlet means for the second vessel whereby said liquid forced from the interface is conveyed to the contaminant separation and containment zone of the secondary vessel. Furthermore, when this secondary vessel is attached to the exterior of the primary vessel, the interfacing bush and spindle means may be arranged to mount the primary vessel with respect to the housing and the interface is lubricated with liquid derived from liquid conveyed to the primary vessel.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawing, in which

Figure 1 is a sectional elevation through a centrifugal separation arrangement in accordance with the invention.

Referring to Figure 1, a first embodiment of centrifugal separator 110 comprises a housing 112 defined by a base 114, adapted to be affixed to the engine block of an internal combustion engine (not shown), and a removable cover 116. The base includes inlet duct means 118, by which contaminated liquid is supplied at elevated pressure, and outlet duct means 120 for drainage of liquid from the housing to the engine sump.

A spindle 122, having longitudinal axis 124, is supported at one end thereof 122_1 by the base and extends through the housing and engages at its other end 122_2 with the cover 116. The inlet duct means 118 extends by way of spindle end 122_1 along the spindle as inlet or spindle passage 118_1 to a cross drilling 119. The spindle end 122_1 is surrounded by a plateau region 125 of the base which defines an axially facing thrust face 126_1 and fixed to the spindle end 122_2, for example by a screw thread, is a flanged part 127 which defines an axially facing

thrust face 126_2 and conveniently mounts the cover with respect to the spindle.

Mounted on the spindle for rotation about the axis 124 within the housing is rotor means 130, comprising a pair of walled containment separation and containment vessels 132 and 232 respectively. The vessel 132 is hereafter referred as "the vessel" or "the primary vessel" and the vessel 232 is hereafter referred to as "the secondary vessel".

The primary vessel 132 is a conventional, annular centrifugal separator canister extending about, and lengthways of, the rotation axis. The canister is bounded radially by an impervious outer side wall 134 between end walls 136 and 138 and by an inner wall 139 forming by a tubular axle surrounding the spindle, these walls defining an annular canister volume 140 for containing liquid. The tubular axle 139 is mounted with respect to the spindle by way of bearing bushes 146_1 and 146_2, each of which is journalled on the spindle in respect of radial forces and flanged to cooperate with the respective thrust faces 126_1 and 126_2 in respect of axial forces. The tubular axle is, between the bushes, spaced from the spindle and defines therebetween an inlet region 160 to which the incoming liquid is supplied at elevated pressure by the spindle passage 118_1 and cross drilling 119. The tubular axle has transfer passage means, indicated generally at 162, comprising one or more through apertures 164 which couple the canister volume, and the pressure therein, to the inlet region and the end wall 138 has one or more tangentially directed reaction nozzles 166 which couple the canister volume to the housing. Thus, in known manner, the high pressure of liquid entering the canister is exchanged as it leaves through the nozzles for a reaction force that rotates the canister and tubular axle about the axis 124, and in doing so, subjects the liquid within the canister volume to centrifugal forces which causes solid contaminants to migrate towards the outer wall and be deposited thereon as a cohesive layer. That is, the canister volume 140 defines a contaminant separation and containment space adjacent to, and extending radially inwardly from, the radially outer wall 134.

However, as a consequence of the vessel 132 being filled with the liquid at elevated pressure derived from the supply to effect rotation, as outlined in the introduction to this specification, the liquid passing therethrough also has a rotation related radial pressure gradient that limits the density of contaminant particles that can efficiently migrate to the outer wall and the effective radius thereof practicable for any particular throughflow rate and rotation speed available thereby. However, known design criteria can provide such canisters that efficiently remove significant, particularly dense, contaminants at modest and readily attainable angular

speeds and radii, and the vessel 132 functions to provide for such separation.

In addition to the high pressure liquid in inlet region 160 transferring to the canister separation and containment space 140, it also provides lubrication for the bearing bushes 146_1 and 146_2, and it is known in the art that some of the liquid escapes through the bushes directly into the housing without being subjected to centrifugal separation forces, the significance of which will soon become apparent.

The secondary vessel 232 has an impervious, radially outer side wall 234 extending about, and lengthways of, rotation axis 124 between end walls 236 and 238, being spaced radially from the outer wall 134 of the primary vessel by circumferentially incomplete spacer spars 239. Radially inwardly from the side wall 234 is an annular contaminant separation and containment zone 240 (hereafter referred to as “the zone”), the radially inner boundary of the zone, as denoted by the broken line 241, being defined by outlet passage means 242 in the end wall 238 which leads externally of the vessel within the housing. The outlet passage means 242 may comprise one or more apertures, in the form of circumferentially extending slots, in the end wall or may comprise an annular gap representing a radial space between the end wall 238 and primary vessel 132, or the spindle 122.

The secondary vessel, that is, radially outer wall 234 and end walls 236 and 238, which define the contaminant separation and containment zone 240 and outlet passage means 242, are conveniently, but not necessarily, formed as a discrete separation and containment module 232_1 arranged to be removably mounted with respect to the primary vessel 132 by way of engagement between the radially extending spars 239 and a radially overhanging lip 136_1 of the end wall 136 of the primary vessel. The module 232_1 is conveniently moulded of plastics material and may include any conventional strengthening features, such as circumferential ribs to enable it to withstand the stresses of high speed rotation and the forces exerted by the liquid and deposited contaminants in the zone 240, although it will be appreciated that insofar as the wall is not that of an internally pressurised canister, unlike traditional constructions, the stress levels are low enough to employ such a material safely.

In respect of the secondary vessel 232, inlet means, indicated generally at 250, comprises the bearing bush 146_1 which effects a divider wall 252 that separates the inlet region from the secondary vessel except for transfer passage means, indicated generally at 262, defined between the bearing surface and the spindle and thrust face 126_2 communicating between

the inlet region 160 and the contaminant separation and containment zone 240. The passage may comprise the natural, but indeterminate, clearance due to manufacturing tolerances, or may include surface features in the surface of the bush to facilitate passage of liquid at a predetermined rate that is, in any event , less than that at which liquid can escape through the outlet passage 242 or would starve the primary vessel with respect to its rotation.

Thus, in operation , it will be seen that the secondary vessel receives contaminated liquid at a lesser rate than the primary vessel and contains only a small volume that is defined by the zone 240 immediately adjacent the outer wall 234 , so that a layer of liquid and contaminants is held against the outer wall 234 to a thickness no greater than the contaminant separation and containment zone 240 defined by the radial position of the outlet passage means. Insofar as such zone is at maximum distance from the rotation axis, centrifugal forces are at maximum and any heavier contaminants are separated from the liquid to and agglomerate form a layer against the wall with the liquid overlying it. Separation can thus continue until the contaminant deposits fill the zone and further contaminants are washed directly through the outlet passage means. The additional mass to be rotated by the reaction turbine of the primary vessel is (apart from the length variations of supporting spars 239) essentially independent of radius, but the centrifugal forces exerted on contaminants in the liquid layer may be considerably increased with radius.

Thus, in operation most of the contaminated liquid supplied to the arrangement 110 uses its energy to effect high speed rotation of the rotor means by passage through the primary vessel 132 but some is diverted by way of the transfer passage means formed by rotating bearing bush 146_2 and is thrown towards the radially outer wall 234 of the second vessel.

After a period of operation which may be shorter than that which effectively fills the primary vessel 132 with separated contaminants, module 232_1 that forms the second vessel can readily be separated from the primary vessel and cleaned or discarded, being replaced with a cleaned or new module. As indicated above, the module may be manufactured from plastics material which enables it to be manufactured cheaply as a “consumable” which can readily be destroyed with the contaminants collected therein.

It will be appreciated that the above described embodiment is open to variation in a number of respects, some of which may be mentioned briefly in what is a non-exhaustive list. The secondary vessel may be dimensioned and/or disposed such that it receives contaminated

liquid by way of the other or both bearing bushes; or from a specific duct in the spindle passage, as shown ghosted at 118_2 which also may be supplied from a different source than duct 118; or by way of one or more through-apertures in a wall of the primary vessel, either specific to this purpose or the reaction jet nozzles 166.

Although it is convenient to surround the radially smaller primary vessel with a radially larger secondary vessel, the vessels may be disposed in line in a non-overlapping relationship that gives greater freedom to their individual dimensions, but possibly making transfer of liquid more complex.

Also, it is possible to provide the secondary vessel, where it is not surrounding the primary vessel, with a radially outer side wall that does not have a greater radius than the side wall of the primary vessel; the relatively thin contaminant separation and containment zone thereof providing a lesser pressure gradient than in the filled primary vessel.

The radially outer walls of the primary and secondary vessels need not extend parallel to each other and it will be appreciated that the outlet passage means may be provided other than in one, or either, end wall of the vessel. The outlet passage means of the secondary vessel may be defined in either or both end walls and/or in the radially outer side wall, provided that the contaminant separation and containment zone is properly defined and liquid exiting the vessel by way of the outlet passage means does not interfere with the rotation. In this context the impervious nature of the radially outer wall should be taken to be exclusive of such outlet passage means.

The secondary vessel may be independently mounted on the spindle rather than attached to the exterior of the primary vessel.

Also, it may be possible to employ a tertiary vessel surrounding the secondary vessel and of the same construction whereby even lower density contaminants can be separated at even greater radial distances without unduly increasing the volume of, or pressure gradient effects in, liquid rotated.

Although the above described embodiment employs a primary vessel that also forms a self-driven reaction turbine rotated by the liquid that is actually subjected to centrifugal cleaning, it will be appreciated that the primary and secondary vessels may be rotated together or

independently of each other by other forms of fluid motor means, such as an impulse turbine (not shown) in which some of the liquid in inlet duct 118 or a separate such duct is directed from stationary nozzles to impinge against turbine blades or buckets carried by the rotor means, spent liquid from the turbine possibly being directed and collected to provide the contaminated liquid for the contaminant and separation zone of the second vessel. Other forms of turbine or non-turbine fluid motors, such as positive displacement types, driven by liquid or gaseous fluids could be adapted for an arrangement in accordance with the present invention, as may non-fluid motor means, such as an electric motor or geared mechanical link to the engine whose lubricant is being cleaned.

Likewise, the embodiment of separation apparatus described has a stationary spindle upon which the rotor means is mounted by way of bearing bushes interfacing therewith. It will be appreciated that such interfacing bush and spindle means may take the form of one or more spindles fixed with respect to, and rotatable with, a vessel and interfacing with bushes fixed relative to the housing.

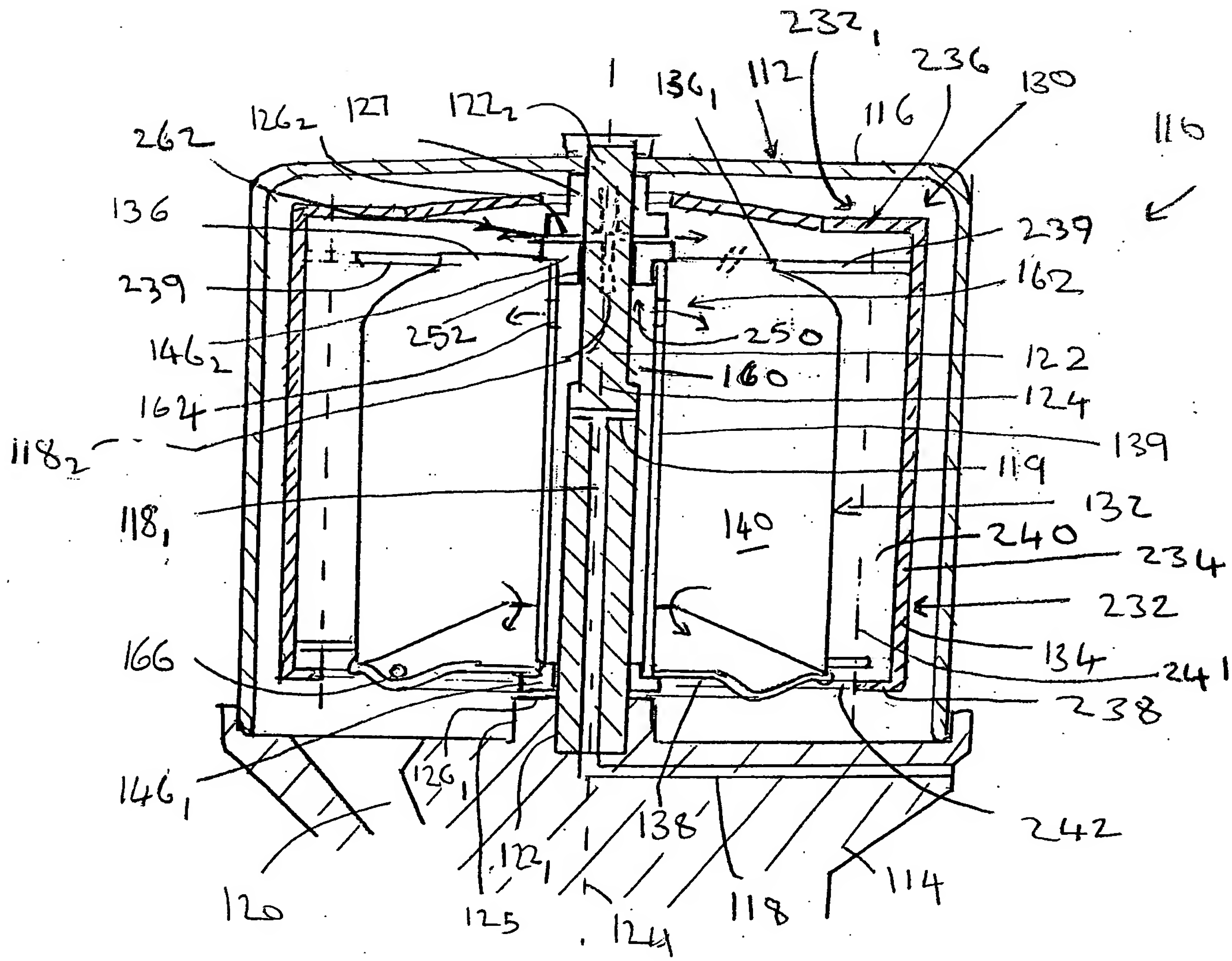

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FIG. 1